Benefits of NPOESS for Commercial Ship Routing – Transit Time Savings

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Introduction

Commercial ships carry more than 90 percent of the world's international trade volume. To keep ships safe from ocean storms and on schedule, the $200 billion global marine shipping industry relies increasingly on marine weather forecasts (Paine 1995). Satellite data can be a valuable input to the models that produce these forecasts. This paper describes the rationale for and practice of commercial ship routing today, and estimates the economic benefit to ship routing from data to be delivered by the planned National Polar-Orbiting Operational Environmental Satellite System (NPOESS).

The approach taken to estimate this benefit is to examine the value provided by ship routing activities with and without the data provided by NPOESS. Future ship routing practice without NPOESS can be extrapolated from present and past experience. With NPOESS, ship routing will benefit from the use of the additional data NPOESS will provide.

Conceptually, the benefits from improved ship routing accrue from tens of thousands of commercial ship transits each year. Improved routing leads to time savings on these transits, which translates into reduced expenditures and a more efficient transportation system. The overall benefit is estimated as the sum of expected average time savings over expected future transits on the main ocean transport routes.

We begin with a description of the challenge posed by ship routing decisions and their economic consequences. We then turn to the response to this challenge – today's ship routing services – and how these might be improved with NPOESS data. Finally, we examine how the economic value of ship routing services is likely to evolve in the next three decades with and without NPOESS.

Description of the Challenge

The world's ocean-going fleet today consists of over 5000 dry bulk vessels, nearly 3000 tankers, and nearly 7000 container-capable vessels (see Tables 1 and 2). The world's container-capable fleet has a total capacity between 5 and 6 million TEU.

Ocean crossings (transits across the Atlantic, Pacific, or Indian Ocean; as opposed to coastal passages) have been the focus of ship routing activities to date. Collectively, the world fleet undertakes in excess of 33,000 ocean transits annually (see Table 3). Ocean transits tend to be carried out by larger vessels. For example, of some 7000

container-capable vessels in the world fleet, there are about 800 large (2000+ TEU) vessels with an average capacity of some 3350 TEU (see Table 2).

	main vessel categories	*typical size (dwt)*	*approx. ships in world fleet, 2000*
dry bulk	Handysize	27,000	2,700
	Handymax	43,000	1,000
	Panamax	69,000	950
	Capesize	150,000	550
tanker	product tanker	45,000	1,400
	Aframax	90,000	700
	Suezmax	140,000	300
	VLCC	280,000	450

Table 1: Approximate number of ships in the world bulk fleets as of 2000.

	< 1,000 TEU	*1,000-1,999 TEU*	*2,000-2,999 TEU*	*3,000-3,999 TEU*	*> 4,000 TEU*	*total*
fully cellular/ converted	983	799	368	217	196	**2,563**
RoRo/container	141	33	9	5	0	**188**
RoRo	705	39	9	1	0	**754**
semi-container	2,729	125	0	0	0	**2,854**
other	397	146	9	0	0	**552**
total	**4,955**	**1,142**	**395**	**223**	**196**	**6,911**

Table 2: Number of ships in the world containership fleet as of Nov. 1, 1999.
Source: Containerization International Yearbook 2000.

	route	*ocean crossing*	*approx. annual ocean transits*	*"average" or "representative" vessel*
tanker	Middle East – Americas	Atlantic	1,000	VLCC (280,000 dwt)
	Middle East – Asia	Indian	3,600	VLCC (280,000 dwt)
	Africa – Americas	Atlantic	1,400	Suezmax (140,000 dwt)
dry bulk	Africa – Asia	Indian	400	Capesize (150,000 dwt)
	Americas – Europe	Atlantic	2,500	Capesize (150,000 dwt)
	Americas – Asia	Pacific	3,500	Cape/Panamax (100,000 dwt)
	Australia – Europe	Indian	700	Capesize (150,000 dwt)
container	Americas – Europe	Atlantic	4,000	2,450 TEU
	Americas – Asia	Pacific	6,000	2,900 TEU
	Europe – Asia	Indian	6,500	3,350 TEU

Table 3: Approximate number of annual ocean transits on major trade routes in 2000. Bulk vessel transits include voyages in ballast.

Effects of Marine Weather on Transportation

Adverse winds, waves, and currents can slow a ship's progress and lengthen a single ocean crossing by days. Table 4 illustrates the value of ship time in terms of charter rates (user cost) and operating costs.

		typical time charter rate ($/day)	typical operating cost ($/day)
dry bulk	Handysize	6,500	3,500
	Handymax	8,000	4,000
	Panamax	9,500	4,500
	Capesize	14,000	6,000
tanker	product tanker	12,000	5,000
	Aframax	13,000	6,000
	Suezmax	16,500	7,000
	VLCC	22,000	9,000
container	400 TEU geared	5,000	2,000
	1000 TEU geared	9,000	3,500
	1500 TEU geared	13,500	4,000
	2000 TEU gearless	18,000	4,500
	3000 TEU gearless		5,200
	4000 TEU gearless		5,500

Table 4: "Typical" time charter rates and operating costs.
Charter rates are rough averages, 1980-2000.

Severe weather is cited as a contributing cause of many maritime accidents. The world fleet's annual "hull and machinery" losses have been estimated at about $2 billion (Kite-Powell 1992). Table 5 illustrates typical vessel prices. In addition to loss of the vessel, weather-related casualties can lead to damage to and loss of cargo, environmental damages due to spills of hazardous materials, and human injuries and deaths.

	typical newbuilding price, $m	typical 10-year old price, $m
Handymax	21	10
Panamax	24	11
Cape	34	17
product tanker	27	13
Aframax	36	15
VLCC	71	22
1500 TEU geared	25	14

Table 5: Representative vessel prices ("average", 1980-2000).

Response: Ship Routing Services

Several private and government marine weather forecast services provide information that is used by mariners in ship routing decisions. Weathernews Inc. (WNI), with headquarters in Tokyo, is a leading provider of ship routing services through its Oceanroutes operation, based in Sunnyvale, California. WNI Oceanroutes services are used to guide some 1500 transits per month, or more than half of all routed ocean transits

today. WNI generates annual revenues of $13-14 million from ship routing services. An estimated 50 percent of ocean transits use some sort of ship routing service at present.

WNI Oceanroutes provides mariners with 8 to 9 day forecast of winds and wave heights at the time of departure, and recommend track options throughout voyage. The forecasts are generated by models that are initialized with sea surface pressure observations.

Effectiveness of current routing

Present ship routing efforts focus on ocean crossings, and not on coastal transits. The primary considerations are wind and wave forecasts; ocean currents – especially wind-driven currents – are not generally forecast because of a lack of data (see McCord *et al.* 1999).

Present routing services are estimated to save about 12 hours on a typical bulker/tanker and 4 hours on a typical container ship Atlantic crossing, and some 12 hours on a typical container ship and 18 hours on a typical bulker/tanker Pacific transit (Oceanroutes, p.c.). Table 6 shows the estimated average time savings per transit for major trade routes and representative vessel classes, possible with today's routing services. We assume that transits that include an Indian Ocean crossing can realize savings similar to Atlantic transits. Transits that follow mainly coastal routes are assumed to benefit little from present routing services.

		"average" vessel	*2000 transits*	*average hours saved per transit*
Atlantic transits	container	2,450 TEU	4,000	4
	tanker	VLCC	1,000	12
	tanker	Suezmax	1,400	12
	dry bulk	Capesize	2,500	12
Pacific transits	container	2,900 TEU	6,000	12
	dry bulk	100k dwt	3,500	24
Indian Ocean transits	container	3,350 TEU	6,500	4
	tanker	VLCC	3,600	12
	dry bulk	Capesize	1,100	12
Middle East - Europe	tanker	Suezmax	3,000	--
Australia - Asia	dry bulk	Capesize	3,300	--
Africa - Europe	tanker	Suezmax	2,000	--
	dry bulk	Handymax	1,400	--
intra-Americas	tanker	Suezmax	4,700	--
	dry bulk	100k dwt	1,000	--
intra-Asia	dry bulk	100k dwt	1,200	--
intra-Europe	tanker	product tanker	6,300	--
total ocean transits			29,600	
total "coastal"			22,900	
grand total			**52,500**	

Table 6: Estimated time savings due to ship routing in 2000.

Improved routing with NPOESS

As mentioned, wind-driven currents are not extensively forecast (or even nowcast) at present due to lack of data. These currents are important for both ocean and coastal transits. Also, sparse pressure data from the South Pacific makes it difficult to provide useful forecasts for that region (Oceanroutes, p.c.). Both of these shortfalls can be addressed with NPOESS data. Five NPOESS satellites are to replace existing NOAA POES (Polar-Orbiting Environmental Satellite) and DoD DMSP (Defense Meteorological Satellite Program) polar orbiters starting in 2007 (NPOESS/IPO 1998a). Relevant NPOESS data records are listed in Table 7.

	EDR 5 sea surface wind	EDR 12 surface pressure	EDR 34 ocean current	EDR 40 ocean waves
horizontal resolution	20 km	25 km	4 km	20 km
mapping accuracy	5 km	7 km	3 km	10 km
measurement precision	1 m/s; 10º	4 mb	0.25 m/s; 15º	0.2 m; 10º
refresh	6 hours	12 hours	TBD (12 hrs obj.)	72 hours

Table 7: Thresholds for NPOESS data records of concern to ship routing.
Source: NPOESS/IPO (1998b).

NPOESS will likely increase the availability of sea surface pressure data, particularly in regions (such as the South Pacific) that are not well served at present. This should help ship routing services improve their forecasts by providing better inputs to their wind and wave forecast models. Direct observation of surface winds and waves will allow routing services to better verify and calibrate their models. Finally, direct observations of surface winds and currents will allow ship routing to provide nowcasts and forecasts of wind-driven currents. Estimates of resulting potential time savings from better wind, wave, and current routing are shown in Table 8. These estimates assume an improvement in average time savings due to NPOESS data of 75 percent over current savings. Note that coastal transits are assumed to benefit from routing under NPOESS, largely due to ocean current information.

Because there is little commercial ship traffic south of 50º S or north of 62º N, ship routing services are not greatly interested in data from the polar regions. More frequent refresh in the tropics and mid-latitudes is more important to ship routing than polar coverage. On balance, therefore, ship routing would likely benefit more from heavy geostationary coverage than polar satellites. Still, NPOESS represents a significant improvement over current data availability.

		"average" vessel	average hours saved per transit	
			present routing (2000)	routing with NPOESS data (est.)
Atlantic transits	container	2,450 TEU	4	7
	tanker	VLCC	12	21
	tanker	Suezmax	12	21
	dry bulk	100k dwt	12	21
Pacific transits	container	2,900 TEU	12	21
	dry bulk	100k dwt	24	42
Indian Ocean transits	container	3,350 TEU	4	7
	tanker	VLCC	12	21
	dry bulk	100k dwt	12	21
Middle East - Europe	tanker	Suezmax	--	4
Australia - Asia	dry bulk	Capesize	--	8
Africa - Europe	tanker	Suezmax	--	8
	dry bulk	Handymax	--	8
intra-Americas	tanker	Suezmax	--	6
	dry bulk	100k dwt	--	8
intra-Asia	dry bulk	100k dwt	--	4
intra-Europe	tanker	product tanker	--	2

Table 8: Estimated potential time savings from ship routing with NPOESS data.

Table 8 describes time savings due to better routing, but does not address damage or losses due to severe weather. Most weather-related damage to commercial ships is due to severe weather events that are forecast reasonably well today. Improved forecasts and nowcasts made possible by NPOESS may lead to reduced weather damage, but the associated savings are difficult to quantify.[1] Many factors other than weather forecasts play a role in marine casualties. These include the fitness of vessel and its crew, and the risk-avoidance behavior of vessel operators. Significant changes are underway in the areas of vessel design (double hulls for tankers, structural aspects of bulk carriers) and crew training. These are likely to have more important effects on maritime safety in the future than improved weather forecasts. It is also possible that mariners will change their risk-avoidance behavior (that is, they may assume greater risks) once better forecasts are available. For these reasons, we do not attempt here to estimate changes in maritime safety due to NPOESS.

Estimate of NPOESS Benefits

To estimate the benefits of NPOESS for ship routing, we compare the expected economic savings from routing during the period from 2007 to 2027 with and without NPOESS data. Present routing benefits (Table 6) serve as a starting point for the

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[1] Parker (1993) cites a study by James Miller of Stanford University of 150,000 transpacific and transatlantic voyages over four year, which found that the casualty rate was 54 percent lower among routed ships. Hull and machinery losses in the world fleet amount to some $2 billion per year (Kite-Powell 1992). If half of these losses are weather-related, and half of those are incurred in ocean as opposed to coastal transits, the annual avoided casualty losses due to routing could be around $150 million.

assessment. To obtain the baseline (no NPOESS) routing benefits for 2007 to 2027, allowance must be made for expected changes in three general parameters: number of transits, operating costs, and improvements in routing effectiveness. Future transit counts are a function of future trade volumes and vessel sizes; their estimation is described below. We assume that average vessel operating costs will remain more or less constant, in real dollar terms, over the future study period. And as discussed below, we assume that average savings from routing services during the study period will increase by 20 percent over present savings.

Recently, both the dry bulk and the liquid bulk (tanker) trade have grown on average by 2 percent per year in ton-miles (total volume was close to 9 trillion ton-miles dry bulk and about 10 trillion ton-miles liquid bulk in 2000). The container trade has grown an average of 7 percent per year in TEU-miles for the past 20 years (volume was about 300 billion TEU-miles in 2000). From 1976 to 1998, the world shipping fleet grew by an average of 1.5 percent per year in deadweight tonnage terms (Lloyd's Register *World Fleet Statistics Tables*, 1999).

		daily op.ex. ($k)	*annual transits*		*average savings from routing (hours/transit)*		
			2000	*2007-27 average*	*2000*	*2007-27 baseline*	*2007-27 NPOESS*
Atlantic transits	container	4.9	4,000	4,800	4	4.8	7
	tanker	9.0	1,000	1,300	12	14.4	21
	tanker	7.0	1,400	1,820	12	14.4	21
	dry bulk	6.0	2,500	3,250	12	14.4	21
Pacific transits	container	5.2	6,000	7,200	12	14.4	21
	dry bulk	5.2	3,500	4,550	24	28.8	42
Indian Ocean transits	container	5.5	6,500	7,800	4	4.8	7
	tanker	9.0	3,600	4,680	12	14.4	21
	dry bulk	6.0	1,100	1,430	12	14.4	21
Mid. East – Europe	tanker	7.0	3,000	3,900	--	--	4
Australia – Asia	dry bulk	6.0	3,300	4,290	--	--	8
Africa – Europe	tanker	7.0	2,000	2,600	--	--	8
	dry bulk	4.0	1,400	1,820	--	--	8
intra-Americas	tanker	7.0	4,700	6,110	--	--	6
	dry bulk	5.2	1,000	1,300	--	--	8
intra-Asia	dry bulk	5.2	1,200	1,560	--	--	4
intra-Europe	tanker	5.0	6,300	8,190	--	--	2
total ocean transits			29,600	36,830			
total "coastal"			22,900	29,770			
grand total			**52,500**	**66,600**			

Table 9: Expected average annual transits and time savings during the 2007 – 2027 study period.

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We assume that the bulk trades will continue to grow at an average rate of 2 percent per year over the study period, and that the container trades will continue to grow at better than 5 percent per year. There is no significant trend at present toward larger ships in the bulk trades, but container ships are expected to increase in size significantly (ships over 10,000 TEU capacity are already being designed). Based on these considerations, we anticipate that average annual transits during the 2007-2027 study period will be 30 percent greater than present transits in the bulk trades and 20 percent greater in the container trades (see Table 9).

Even if there are no NPOESS data, ship routing services can be expected to improve in the future. New data sources are likely to be developed, and refinements in modeling will lead to improved forecasts. Therefore, our baseline (no NPOESS) estimate of routing savings during the study period assumes 20 percent greater time savings than present routing can achieve. The future baseline still assumes no savings in "coastal" transits, which will derive primarily from the ocean current observations from NPOESS.

With NPOESS, we assume that average time savings on ocean transits will improve by 75 percent over present savings. In addition, we expect time savings to be realized with NPOESS in "coastal" ocean transits, primarily due to routing for wind-driven currents. The estimates for these savings are shown in Table 9.

From the data in Table 9, it is possible to calculate the expected potential benefits due to ship routing at present and in the future under the baseline and the NPOESS scenarios. The results of this calculation are shown in Table 10.

The results of this estimation suggest that the annual benefit generated by ship routing from transit time savings is at present close to $80 million per year. The estimated baseline benefit during the 2007 – 2027 study period, without NPOESS, is about $120 million per year. With NPOESS, the potential savings will be in excess of $215 million annually. Of this, some $175 million will come from ocean transit routing, and about $40 million will come from coastal transit routing. The difference between the future baseline and NPOESS scenarios – about $95 million per year – is the expected average annual benefit to ship routing from NPOESS data in the two decades following the launch of NPOESS in 2007.

These future costs and benefits are rough estimates in year 2000 dollars. Future costs and benefits have not been explicitly inflated or discounted in this analysis. Because the shipping business is highly competitive, benefits from better routing will accrue largely to shippers and, ultimately, to consumers. These benefits will, therefore, be shared broadly by the world's consumers of internationally traded goods. Because of its share of world trade, perhaps 20 percent of the total benefit – some $20 million per year – will be realized by consumers in the United States.

		annual transits		savings from routing ($m/year)		
		2000	2007-27 average	2000	2007-27 baseline	2007-27 NPOESS
Atlantic transits	container	4,000	4,800	3.3	4.7	6.9
	tanker VL	1,000	1,300	4.5	7.0	10.2
	tanker Sz	1,400	1,820	4.9	7.6	11.1
	dry bulk	2,500	3,250	7.5	11.7	17.1
Pacific transits	container	6,000	7,200	15.6	22.5	32.8
	dry bulk	3,500	4,550	18.2	28.4	41.4
Indian transits	container	6,500	7,800	6.0	8.6	12.5
	tanker	3,600	4,680	16.2	25.3	36.9
	dry bulk	1,100	1,430	3.3	5.1	7.5
Mid. East – Europe	tanker	3,000	3,900	--	--	4.6
Australia – Asia	dry bulk	3,300	4,290	--	--	8.6
Africa – Europe	tanker	2,000	2,600	--	--	6.1
	dry bulk	1,400	1,820	--	--	2.4
intra-Americas	tanker	4,700	6,110	--	--	10.7
	dry bulk	1,000	1,300	--	--	2.3
intra-Asia	dry bulk	1,200	1,560	--	--	1.4
intra-Europe	tanker	6,300	8,190	--	--	3.4
total ocean transits		29,600	36,830	79.4	120.9	176.3
total "coastal"		22,900	29,770	--	--	39.2
grand total		**52,500**	**66,600**	**79.4**	**120.9**	**215.7**

Table 10: Estimated annual savings from ship routing.

Summary/Conclusion

The potential value of ship routing in transit time savings alone is, at present, close to $80 million for the world fleet. (In practice, only about half of current ocean transits take full advantage of available routing services, so that not all of these time savings are realized.) Additional value – the amount is uncertain, but could also be in excess of $100 million per year – is generated by the avoided casualty losses due to ship routing for severe weather avoidance.

NPOESS data will enable better ocean transit routing through better sea surface pressure data and improved wind and wave forecasts. NPOESS will also allow nowcasting and forecasting of ocean currents, which will allow improved routing of coastal transits as well as ocean crossings. The incremental benefit from commercial ship transit time savings with NPOESS data is estimated to be on the order of $95 million per year in the two decades following the initial NPOESS deployment (2007). This estimate does not include possible additional benefits from improved casualty avoidance, and therefore should be considered a lower bound estimate of total NPOESS benefits to ship routing. About 20 percent of this benefit will be realized by consumers of internationally traded goods in the United States.

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